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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

Letter
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MOTOR LUBRICATING OILS

This Bureau has frequent requests for information regarding the relative merits of competitive trademarked products, as, for example, motor lubricating oils. It is the policy of the Bureau to decline to supply such information although in so doing it may appear to be withholding from the public information to which the latter is entitled.

Without mentioning numerous specific reasons that could be given for the adoption of such a policy, it may be stated that experience has shown that the Bureau renders a greater ultimate service by adhering to such policy than would be possible if comparative results of tests of commercial articles were distributed frequently with the Bureau's name attached.

In practice, the above policy permits the Bureau to perform a wide variety of tests and studies, as a result of which it becomes possible to distribute to the public information as to the desirable characteristics of various types of products, and to cooperate with manufacturers in improving their products and processes.

Existing evidence indicates that differences in the service performance of well-refined motor lubricating oils are probably small. This not only makes it less important that differences in the quality of such oils be known than would otherwise be the case, but makes the determination of such differences difficult. Furthermore, the fact (1) that the quality of an oil is determined by many factors, some of which may be unknown, or at least are not commonly specified; (2) that knowledge of the relation of the various properties to service performance is incomplete; and (3) that the relative importance of the various properties depends upon the service in which the oil is to be used, - all make it evident that motor lubricating oils, as compared with many other commodities, offer peculiar difficulties in any attempt to rate them according to quality.

The following discussion of some general considerations applying in the choice of a motor lubricating oil may be of aid in obtaining a satisfactory oil for a given service.

It seems rational to consider the choice of a motor oil from two general standpoints: (1) its initial suitability; (2) its stability, or conversely, its rate of deterioration, in service.

Viscosity is undoubtedly the most important property in judging the initial suitability of an oil for a given service, since it is this property of the oil that prevents abrasion of the "rubbing" surfaces.

In motor engine operation, due to variation in engine temperature, and to the decrease in the viscosity of mineral lubricating oils with increasing temperature, the viscosity of the oil varies from that existing under starting conditions as a maximum, to the minimum, that occurs when the engine is up to running temperature. The viscosities under both conditions are of importance. The former determines the ease with which the motor may be started, as well as the facility with which the oil distributes, when cold, to the bearing surfaces. The latter is probably of primary importance in choosing an oil, both because it determines very largely the power loss, and because most engine failures chargeable to the oil probably occur under running conditions, that is when the viscosity of the oil is a minimum.

The performance of an oil, in so far as it depends on viscosity, is judged by the viscosity at the standard temperature of test (usually 100°F for motor oils). The pour point in addition is often considered to give an indication of the starting characteristics of an oil, but it should be said that the latter property is not in general a satisfactory measure of the flow characteristics of an oil under all conditions at low temperatures.

In considering viscosity, it is well to remember that it is the viscosity at the operating temperature that is of importance. Different oils, particularly when refined from different crudes, may have identical viscosities at one temperature in the operating range, and different viscosities at another. For this reason not only may one oil be preferable to another, but also, when replacing one brand of oil by another, it may be desirable to choose a new oil of different viscosity than the old, both as measured at the standard temperature of test, in order that the viscosities of both oils be not too far different at some chosen operating temperature.

In general a wide range of viscosity exists between incipient failure of the lubricating films due to low viscosity, and incipient failure of the lubricating system (imperfect dis-

tribution of the oil to the surfaces to be lubricated) due to high viscosity. If optimum operating conditions could be maintained, a given engine probably could be operated successfully with an oil of as low viscosity as 100 seconds and likewise with one as high as 1000 seconds, (both as determined at 100°F), or even much higher, the extreme limits never having been determined. At the lower extreme, the factor of safety would be too small, while toward the upper, the power loss would be excessive. The proper choice lies between the two extremes, and is thus a compromise between maximum factor of safety and minimum power loss.

The selection of the most suitable viscosity for a given service is often difficult for a user of oils. A certain amount of engineering knowledge or advice is desirable. It is probably wise to rely on the advice of the manufacturers of the equipment to be lubricated, or on the recommendations of reputable oil refiners.

Unfortunately there is at present no generally recognized method of branding or marking oils according to their viscosities. Hence, one refiner's oil of a given grade, for example medium, does not necessarily have the same viscosity as another medium oil.

In concluding the discussion of viscosity it should be emphasized that although viscosity is probably the most important property of an oil, no particular kind or quality of oil has a monopoly of any particular viscosity, as almost any viscosity can be and is produced in any kind or quality of petroleum lubricating oil.

Due to their inherent instability under the necessary conditions of service, all motor oils undergo changes during use. The changes believed to occur are (1) "cracking", or decomposition of the oil into lighter compounds and a carbonaceous residue, and (2) oxidation, or combination with oxygen to form organic acids and other products of an asphaltic nature, which are called asphaltenes.

In the automobile engine cracking takes place probably only in the combustion chamber, the carbonaceous residue going to make up the so-called carbon found there.

The carbon residue test is supposed to be a measure of the "carbon" formed on cracking an oil.

The oxidation of an oil probably takes place chiefly in the crankcase, being accelerated if the oil is highly heated.

The asphaltenes so formed cause dark red discoloration of the oil and some increase in its viscosity. Asphaltenes in solution are probably not harmful, but, if formed in excess, they may be precipitated out, and in such case appear to form a binder that aggregates the dust, metallic particles and finely divided carbon which works down from the combustion chamber. Since these aggregates tend to clog small lubricating oil passages, they may cause complete failure of the lubrication to one or more bearings.

The tendency of an oil to form asphaltenes (oxidize) may be measured by some form of oxidation test. While a number of such tests have been devised, none is at present commonly included in oil specifications.

The acidity, emulsion and demulsibility tests, the two latter not always being included in motor oil specifications, are also perhaps related to the stability of oils. In addition, acidity may be a measure of the tendency of an oil to corrode, although it appears that the acidity of well refined oils is nearly always, if not invariably, of organic origin, and hence is so weak that it causes no appreciable corrosion.

The color of an oil is possibly an indication of the foreign matter present, and hence may be related to its stability, as impurities are known to accelerate oxidation. Oil refiners lay considerable stress on color, apparently because they can tell therefrom to what refining processes the oil has been subjected.

The flash and fire points may be considered rough measures of volatility, and hence may be related to the rate of oil consumption, exclusive of oil leaks in the engine.

Lubricating oil specifications, giving numerical values of the commonly specified properties for oils of various viscosities are published in various places. Federal Government Specifications are given in U. S. Bureau of Mines Technical Paper No. 323A, entitled U. S. Government Specifications for Lubricants and Liquid Fuels and Methods for Testing, which publication is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the price of 15 cents (stamps not accepted). At the end of this letter there are given U. S. Government Specifications for motor lubricants, as laid down in the above mentioned publication.

Ordinary routine tests on oils are made at this Bureau only at the request and for the information of agencies of the Federal, State, and Municipal Governments. It is believed that such tests

for the general public can best be handled by the commercial testing laboratories specializing in such work. A list of such laboratories can be supplied by this Bureau.

In current automotive equipment, operating on present day fuels, the lubricating oil is often rendered unfit for use by what may be called external contaminants, long before it would have deteriorated badly due to its own inherent instability. Obviously, external contamination is a matter broadly speaking of operating conditions, and hence lubrication failures due to such causes are not properly chargeable to the oil.

It is common knowledge that the oil in the crankcase of an automobile loses viscosity in service. This loss in viscosity is due to dilution of the oil bv the less volatile constituents of the fuel. Examination of used oils shows that under ordinary conditions of summer driving dilutions of from 10 to 20% are common, whereas dilutions from 20 to 50% prevail under winter conditions.

The affect of dilution on the viscosity of an oil is approximately as given in the following table.

Effect of Dilution on Viscosity

Viscosities at 100°F, Seconds, Saybolt Universal Viscosimeter.

New Oil	300	600	1000	4000
10% dilution	168	315	500	1450
20% "	115	178	250	510
30% "	71	95	125	200
40% "	44	54	63	83
50% "	--	--	32	45

As a result of the loss in viscosity, the most essential characteristic of the oil, the latter works past the piston more readily, causing increased oil consumption, excessive carbon formation and fouling of spark plugs. As the diluted oil will not maintain a lubricating film under as high bearing pressures as will the oil of higher viscosity, excessive wear and even seizure of bearings may ensue.

Fortunately dilution does not in general increase indefinitely in amount, but tends rather to attain an equilibrium, which is reached in perhaps 100 or 200 miles running on the average. Hence expedients that tend to keep the dilution at a

low figure are particularly important. Some of these are: reducing the warming up period, for example by the use of a radiator shutter, hood cover, etc., using a water thermostat to maintain fairly high jacket water temperature; employing lean mixtures, and avoiding excessive use of the choke. Without considering just what viscosity may represent the permissible safe minimum, the data given in the table above indicate that in view of probable starting difficulties if too high viscosity is chosen, it is hardly feasible to take care of high dilutions by the use of extremely viscous oils.

Another harmful external contaminant is road dust, which may be highly abrasive. Possibly the harmful effects of dust are greater with the thin (diluted) oil, since the film thickness probably is smaller in such cases. Maintaining a suitable viscosity in the oil will probably reduce wear on the bearing surfaces to some extent.

Still a third contaminant, sometimes troublesome, particularly in cold weather, is water, which is formed in the combustion of gasoline in the proportion of about one gallon of water for each gallon of gasoline burned. The greater part of this water passes out with the exhaust gases, but some may blow by the piston into the crankcase. In cold weather this may be condensed and may form troublesome emulsions with the oil, which have the appearance and consistency of heavy greases. Water also may cause troublesome corrosion, or may collect and freeze in such parts of the lubricating system as to cause complete failure of lubrication.

Periodic draining, and if possible cleaning (flushing) of the crankcase, is essential in order to remove the diluted oil and the accumulation of dust. Probably the frequently recommended practice of cleaning the crankcase every 500 miles is, under present conditions of operation, desirable, if not essential to economical upkeep.

Another common inquiry relates to the differences between lubricating oils refined from the paraffin and naphthene base crudes.

At the present time, due to the diminishing supply of paraffin crude, the straight paraffin lubricants constitute a rather small percentage of those available, the great majority now on the market being refined from naphthene or from mixed base crudes, or blended from lubricating stocks from different crudes.

While the laboratory properties of a lubricating oil depend largely on the refining to which it has been subjected, when oils of the same viscosity at the standard temperature of test are compared, the paraffin and naphthene lubricants are found

to differ from each other in general as follows:

The change of viscosity with temperature is less for the paraffin than for the naphthene.

The specific gravities of the paraffin oils are lower, that is, gravities A.P.I. are higher.

The carbon residue value is higher for the paraffin oils.

The pour point is higher for the paraffin oils.

The flash and fire points are higher for the paraffin oils.

Oils refined from mixed base crudes, and those blended from stocks from different crudes, have characteristics intermediate between the paraffin and naphthene lubricants.

While much has been said regarding the relative merits of lubricants refined from the two types of crude, and there are decided and honest differences of opinion among both producers and users, this Bureau as yet has no evidence which indicates the marked superiority of either type oil for use in the lubrication of automobile engines if suitable choice of viscosity is made in each case.

U. S. Government Specifications for Motor (Class D) Lubricants.

Grade	Flash, minimum	Fire, minimum	Viscosity, Saybolt Seconds 100°F Minimum	Viscosity, Saybolt Seconds 100°F Maximum	Viscosity, Saybolt Seconds 210°F Minimum	Viscosity, Saybolt Seconds 210°F Maximum	A.S.T.M. Color, undiluted	A.S.T.M. Color, diluted 85%	Pour, maximum	Acidity, maximum mg KOH per gram	Corrosion test	Carbon residue, maximum
	°F	°F	sec.	sec.	sec.	sec.			°F			percent
Extra light	315	355	135	165			7		35	0.30	Required for all grades	0.10
Light	325	365	180	220			7		35	.30		.20
Medium	335	380	270	330			7-1/2		40	.30		.45
Heavy	345	390	360	440			8		45	.30		.55
Extra heavy	355	400	450	550			8		50	.30		.70
Ultra heavy	360	410			55	65		5	50	.30		.80
Tractor	380	430			75	85		6	50	.30		1.50
Tractor, hvy	390	440			90	100		7	50	.30		1.75
Motor cycle	400	450			110	120		8	50	.30		2.00

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1 Can make analyses of ... [illegible] ... of gasoline content.
1* Can not determine gasoline content.
2 Can examine crude oils, oil shales, and ... [illegible]
2* Can do only a limited amount of work.
3 Can undertake petroleum problems of a research nature.
3* Can undertake research work of minor nature or scope.
? Did not answer regarding 1, 2 and 3.
A Engler
B Special steam method.
C Parr peroxide bomb.

Test columns (headings printed vertically, partly illegible): Color by ... colorimeter; Cloud and pour points; Viscosity lubricating oils; Vis... [illegible]; Vis... at 77°F.; ... [illegible]; Distillation ... gasoline; Dis... [illegible]; ... [illegible]; ... [illegible]; Or... [illegible]; Soot test; Flock test for kerosene; Fl... test ... signal oil; Wick-feed test; Burning test ... [illegible]; Burning test ... [illegible]; " ... long-time burning; " ... [illegible]; " signal oil; Water; Sediment; Water and sediment, centrifuge; Water by centrifuge; Precipitation number; Emulsion test 130°F.; Emulsion test 180°F.; Demulsibility at 130°F.; Demulsibility at 180°F.; Protection test; Oven salt-spray rain test; Breakdown test; Carbon residue; Reaction test; Acidity in gasoline; Free acid; Sulphur in burning oils; Sulphur in fuel oil; Doctor test; Corrosion (copper dish); Corrosion at 122°F.; Corrosion at 212°F.; Five-day corrosion test; Saponification number; Fatty oil; Unsaturation in gasoline; " in transformer oil

State	Laboratory	Class	Tests
DC	Industrial Research Labs., 1845 B St., N.W. Washington	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
MASS	Arthur D. Little Inc., Charles River Road, Cambridge	1*2	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
NJ	Newark Industrial Labs., 96 Academy St., Newark	1 2 ?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
NY	Bull & Roberts, 50 West St., New York	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Electrical Testing Labs., 80th St. & East End Ave., NY	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	New York Testing Labs., 80 Washington St., New York	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Ricketts & Co., Inc., 80 Washington St., New York	?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Stillwell & Gladding, 95 Front St., New York	1 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	United States Testing Co., Inc., 316 Hudson St., NY	?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
PA	Gulick-Henderson Co., 534 Fourth Av., Pittsburgh	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Penn American Refining Co., Oil City	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Pittsburgh Testing Lab., 616 Grant St., Pittsburgh	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
RI	Saunders & Franklin, 184 Whittier Ave., Providence		X X X X X X X X
CAN	J.T. Donald & Co., Ltd., 40 Belmont St., Montreal	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
ALA	Pittsburgh Testing Lab., Birmingham		A A A X X X X X X X X X X X X X X X X X X
GA	The Dumas Laboratory, 142½ Peachtree St., Atlanta	2	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
LA	Wm. P. Nelson Jr., 904 Canal-Commercial Bldg., New Orleans	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Herbert E. Shilstone Co., 302 Camp St., New Orleans	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
TENN	Barrow-Agee Laboratories, Memphis	2 3*	Practically all tests
ILL	Armour Inst. of Technology, Chicago	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Chicago Paving Labs., Inc., 160 N. Wells St., Chicago	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Commercial Testing & Eng. Co., 1785 Old Colony Bldg. "	1*2	X X X X X X X X X X X X X X X X X X X X X
	Dearborn Chemical Co., 332 S. Michigan Ave., Chicago		X X X X X X X X X X
	Deavitt Laboratories, 209 S. La Salle St., Chicago	1 2 3	Practically all tests
	Walter H. Flood & Co., 742 E. 39th St., Chicago	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Robert W. Hunt & Co., 2200 Insurance Exch., Chicago	1*2	X X X X X X X X X X X X X X X X X X X X X X X X X
	Mariner & Hoskins, 111 W. Monroe St., Chicago	1 2 3*	Practically all tests
	University of Illinois, 107 Chemistry Bldg., Urbana	1 2	Routine analysis of lubricating oils
	F. E. Martin & Co., Lake Bluff	?	X X X X X X X X X X X X X
IA	Iowa State College, Ames	1*2*3*	X X X X X X X X X X X X X X X X X X X X X
	Monroe L. Patzig, 206 - 11th St., Des Moines	2 ?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
MICH	Detroit Testing Lab., 3726 Woodward Ave., Detroit	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
MINN	University of Minnesota, Minneapolis	2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Van Cleve Labs., Inc., 32? Fourth St., S., Minneapolis	2 3*	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
MO	Kansas City Testing Lab., Inc., 700 Baltimore Ave., K.C.	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Waring & Williams Labs., 6?0 Joplin St., Joplin	2	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
OHIO	Crowell & Murray, 406 Perry-Payne Bldg., Cleveland	1*2	X X X X X X X X X X X X X X X X X X X
	James H. Herron Co., Herron Bldg., Cleveland	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Charles F. Long, 141 East Broad St., Columbus	2 ?	All tests with a few minor exceptions
OKLA	Tulsa Laboratories, 208 Fisher Bldg., Tulsa	1 ?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
ARIZ	Mohave Assay & Eng. Office, P.O. Box 827, Kingman	?	X X X X X X X X X
	A. L. Pellegrin & Son, 100 S. Stone Ave., Tucson	2	X
CAL	Atkin & McRae, 1008 S. Hill St., Los Angeles	2	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Baverstock & Payne, 223 W. First St., Los Angeles		Not all tests On research work furnish advice only
	Industrial Testing Lab., Pico & L.A. Sts., "	1 2 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Smith-Emery Co., 245 S. Los Angeles St., "	1 ? 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Smith-Emery Co., 651 Howard St., San Francisco	1 ? 3	Practically all tests
COLO	Victor Blanc, 1709 California St., Denver	?	X X X X X X X X X X
	Walter E. Burlingame, 1915 Lawrence St., Denver	1 ? 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Paul S. Nice, 31? Seventeenth St., Denver	1	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	J. W. Richards & Son, 1118 Nineteenth St., Denver	2	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	University of Colorado, Boulder	?	X X X X X X X X X X X X X X X X X X X X X X X X X X
N MEX	New Mexico School of Mines, Socorro	1 ? 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
ORE	Oregon Independent Testing Lab., 3d & Yamhill, Portland	2	X X X X X X X X
TEX	Agric. & Mech. Col. of Tex., Dep't. Chem., College Sta.	?	X X X X X X X X X X X X X X X X X X X X X X X X
	Fort Worth Labs., 828½ Monroe St., Ft. Worth	1 ? 3	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Houston Labs., 215½ Main St., Houston	?	X X X X X X X X X X X X X X X X X X X X X
UTAH	R. F. Officer & Co., 169 S. W. Temple St., Salt Lake City	1 ?	X X
WASH	Sumarius & Knisely ..., 114 ... St., Seattle	? ? ?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Geijsbeek Engineering Co., 6? ... Bldg., Seattle	1 ?	[illegible] t all tests
	I. F. Laucks, Inc., 9... St., Seattle	? ? ?	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
	Pacific Coast Testing Lab., 607 Third Ave., Seattle	?	Practically all tests

100.1 ... 290.4 [illegible] 300.1 300.2 300.3 310.1 320.1 320.2 320.3 320.4 400.1 400.2 410.1 500.1 510.1 510.2 510.3 520.1 520.2 520.3 530.1 530.2 530.3 530.4 540.1 540.2 550.1 550.2